INSIDE

Stadtwerke München GmbH
Innovative Energie Pullach
Karlsruher Institut für Technologie

The INSIDE research project

Investigating the relationship between seismicity, deformation and deep geothermal exploitation in the Greater Munich

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SWM

IEP INNOVATIVE ENERGIE PULLACH

ERDWERK

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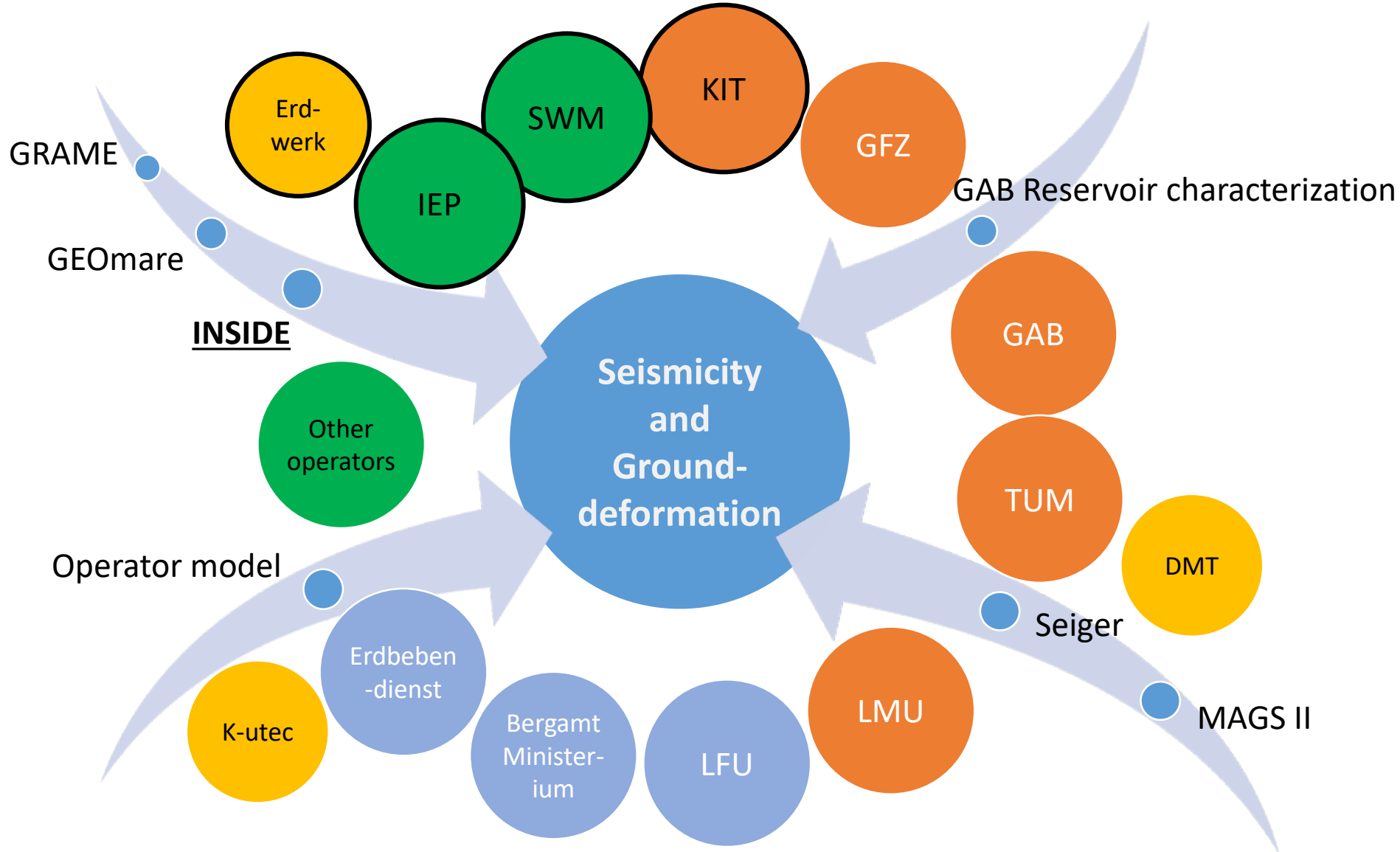
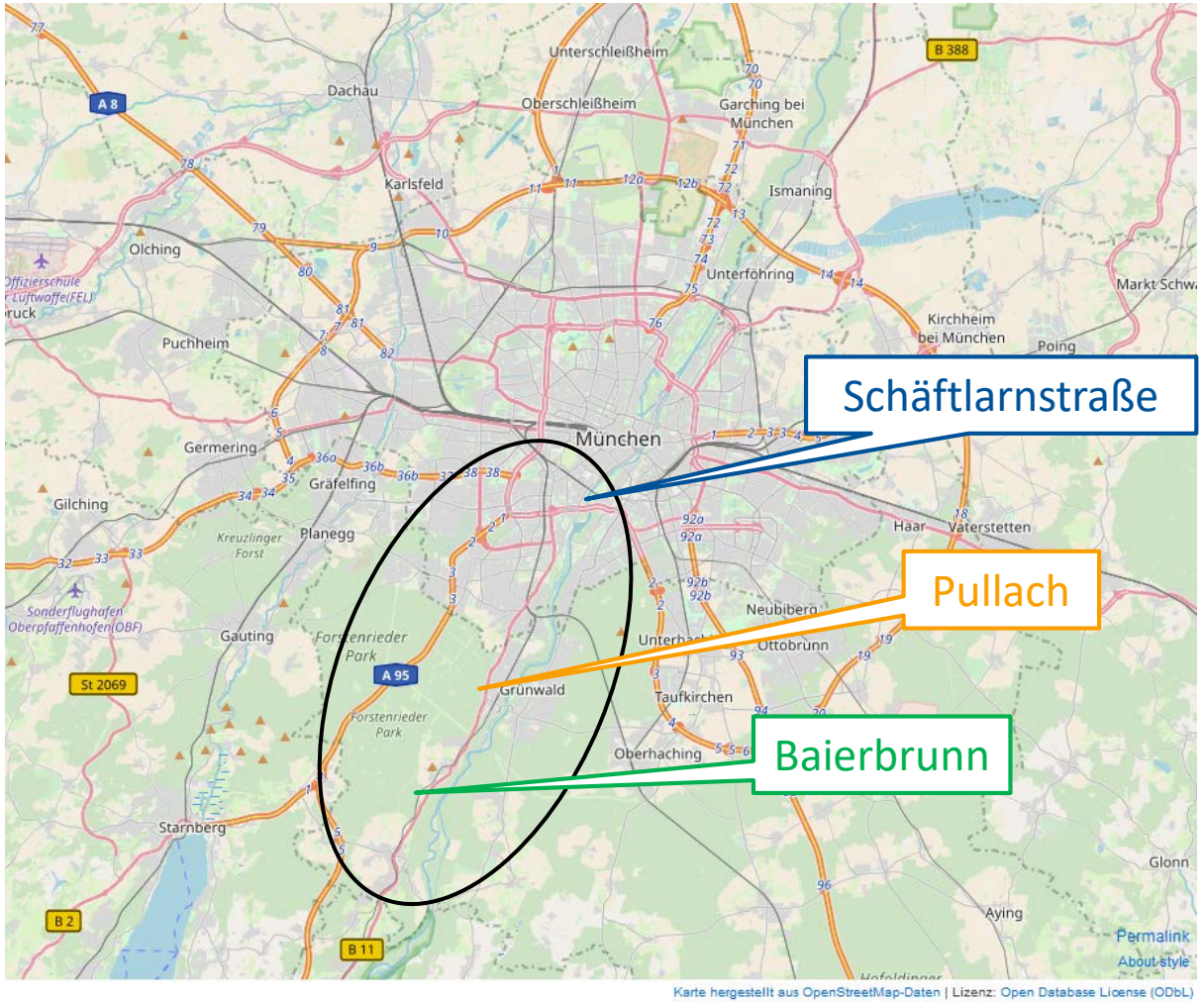
Project “environment”



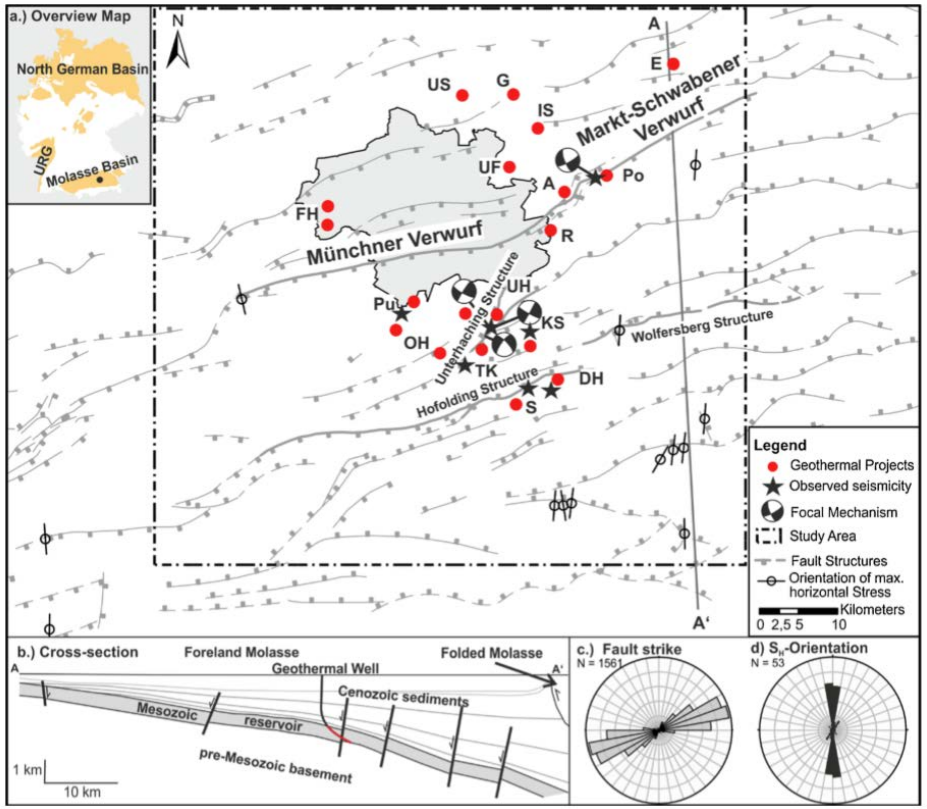
INSIDE Project

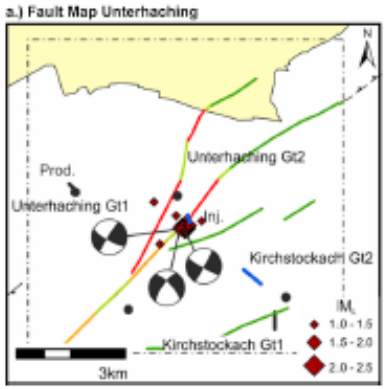
- Partners: IEP, SWM, KIT, *Erdwerk*
- 3 years project: 09.2019 – 08.2022
- Budget: 4.7 M€
- Greater Munich area
- Objective
  - Better understand the relationship between seismicity, deformation and deep geothermal exploitation
- Mean
  - Seismicity monitoring, processing and interpretation
  - Deformation monitoring, processing and interpretation
  - T-H-M-Seismic reservoir modelling
  - Comparison of reservoir modelling and observations

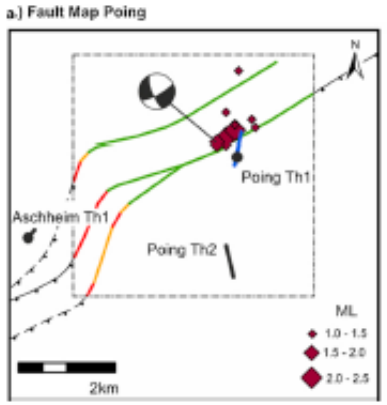


Motivation: Better understanding

Developments of EGS induce seismicity.
Also in deep hydrothermal systems seismicity can be induced!







(Seithel et al., 2019, Geothermics)

Geothermics 52 (2014) 36–49

Contents lists available at ScienceDirect

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Microseismicity observed at a non-pressure-stimulated geothermal power plant

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ABSTRACT

In the North Alpine Foreland Basin, geothermal plants exploit a deep natural aquifer. Considering the low seismic hazard in this region, the non-pressure-stimulated, hydrothermal usage of this aquifer was generally assumed to be unproblematic with regard to induced seismicity. However, a series of five, partly felt shallow magnitude $M_L > 2$ earthquakes at a geothermal power plant near Munich, Germany, lead us to conduct a detailed study of the local microseismicity.

Here, we present results from two years of data acquired with a local five station seismic network. More than 130 events have been detected with local magnitudes ranging from −0.8 to 2.4 and a magnitude of completeness of around 0. Absolute locations are calculated in a 3D velocity model and are improved by

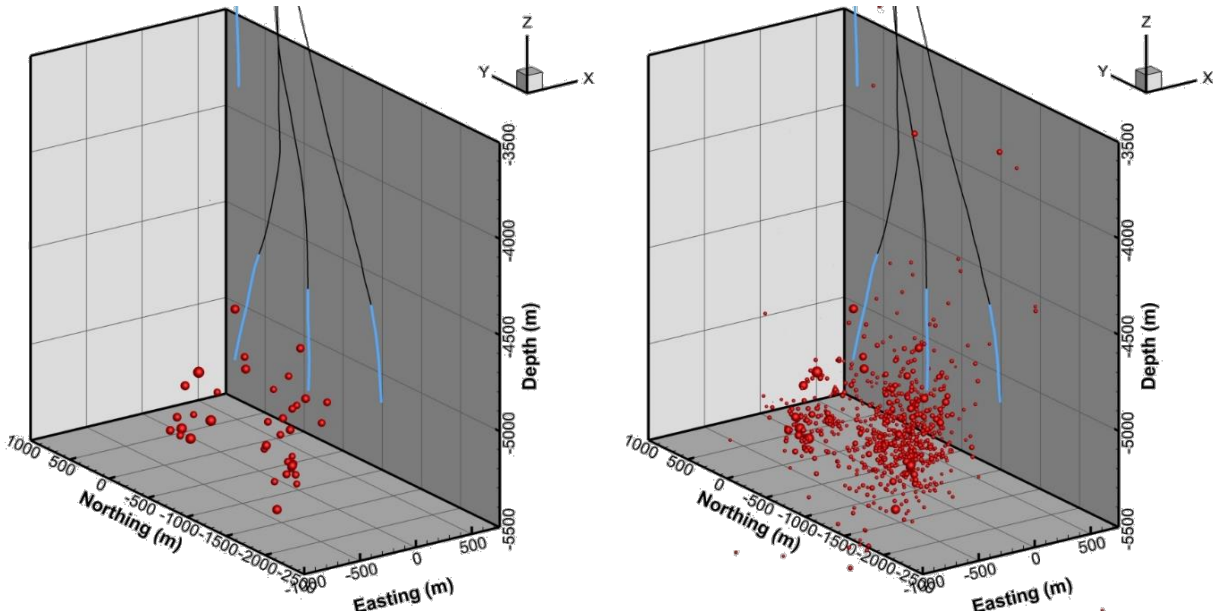
Site	First detection	Strongest event / Event number
Unterhaching (UH)	10.02.2008	M_L 2.4 / 657
Taufkirchen (TK)	19.07.2012	M_L 0.3 /11
Kirchstockach (KS)	23.08.2012	M_L 0.8 /33
Sauerlach (S)	19.06.2014	M_L 1.2 / 2
Pullach (Pu)	21.02.2015	M_L -0.4 / 1
Oberhaching (OH)	01.02.2016	M_L 0.5 / 3
Duernhaar (DH)	31.07.2016	M_L 1.3 / 10
Poing (PO)	19.11.2016	M_L 2.1 / 21

⇒ **Need to improve process understanding**
⇒ **Need to model reservoir**

Motivation: Higher resolution

- Gutenberg-Richter law

$$Log(N_{\leq ML}) = a - b\ M_L$$



Events with $M_L \geq 1$ (42) | All events (868)

Soultz, circulations 2005-2010, surface

⇒ More weak events than strong ones

- Rupture area

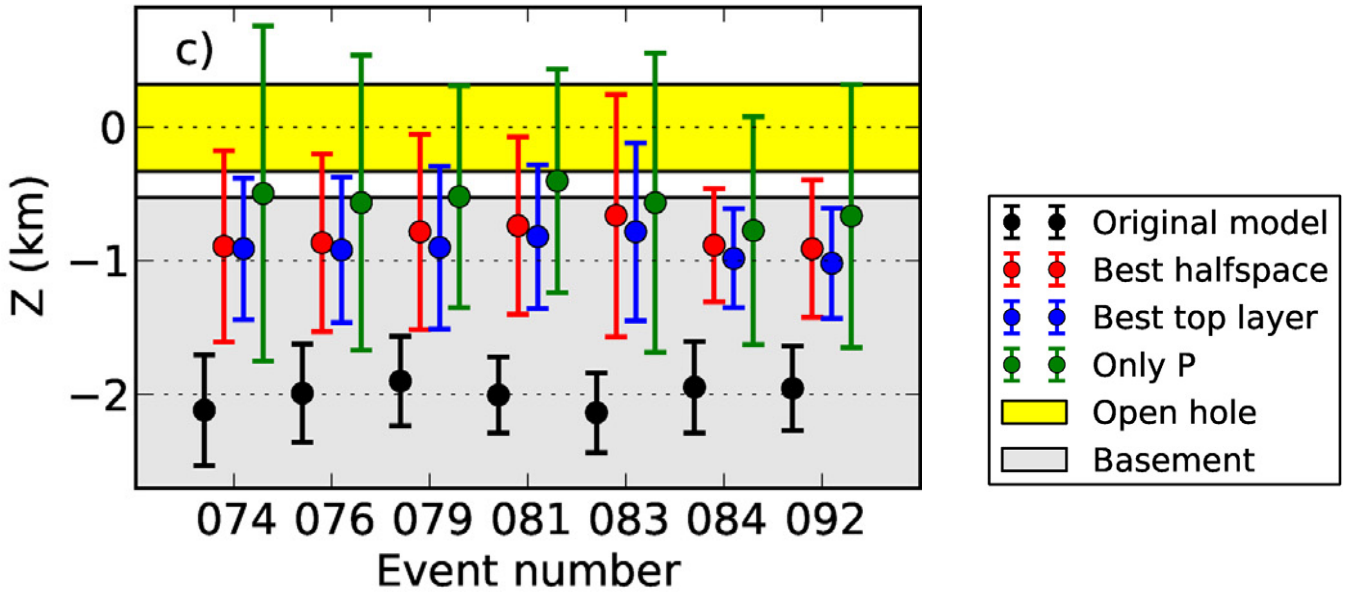
Magnitude	Rupture area	Displacement
5	3 x 3 km²	5 mm
4	1 x 1 km²	0.25 mm
3	316 x 316 m²	10 µm
2	100 m x 100 m	0.5 µm
1	31 m x 31 m	20 nm
0	10 m x 10 m	1 nm
-1	3 m x 3 m	0.04 nm
-2	1 m x 1 m	0.002 nm

⇒ Strong events highlight large faults

⇒ Weaker events can highlight smaller faults

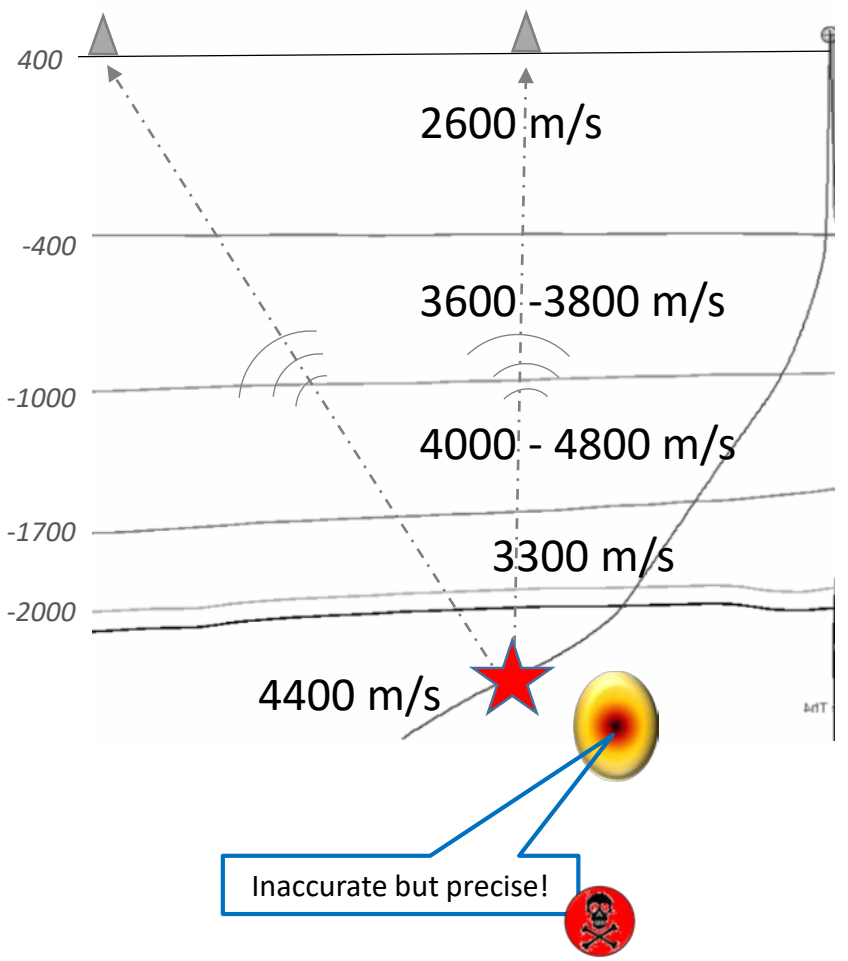
⇒ **Need to access small magnitude events**

Motivation: Higher resolution



Unterhaching Seismizität (2010)

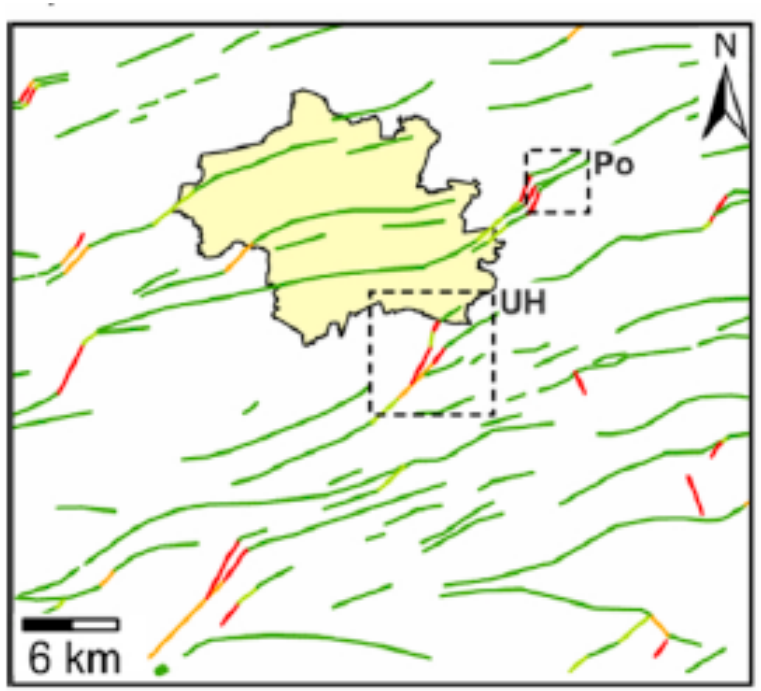
(Megies & Wassermann, 2014, Geothermics)



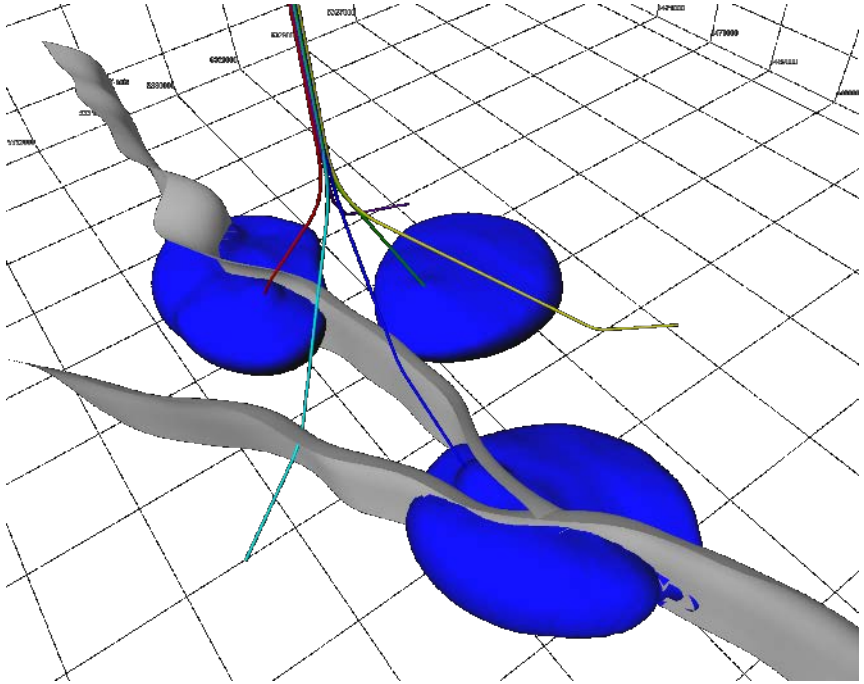
⇒ **Need to describe P- and S-wave velocity models as best as possible**

Motivation: Modelling vs. observations

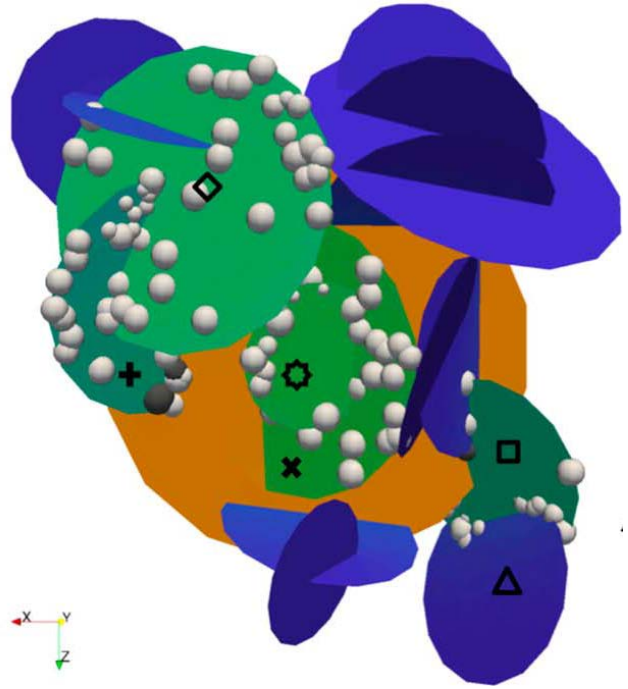
- Thermo-hydro-mechanical-seismic reservoir modelling
- Observations used to calibrate and asses model, for history matching



(Seithel et al., 2019, Geothermics)



(Erdwerk, 2018)



(Ucar et al., 2017, GRL)

Expectation

- **“Reservoir Management System” prototype**
  - **Tune exploitation to minimize risks associated with seismicity or deformation**

Passive seismic monitoring design

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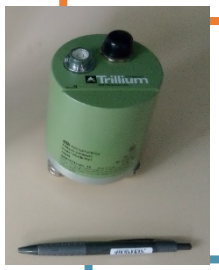
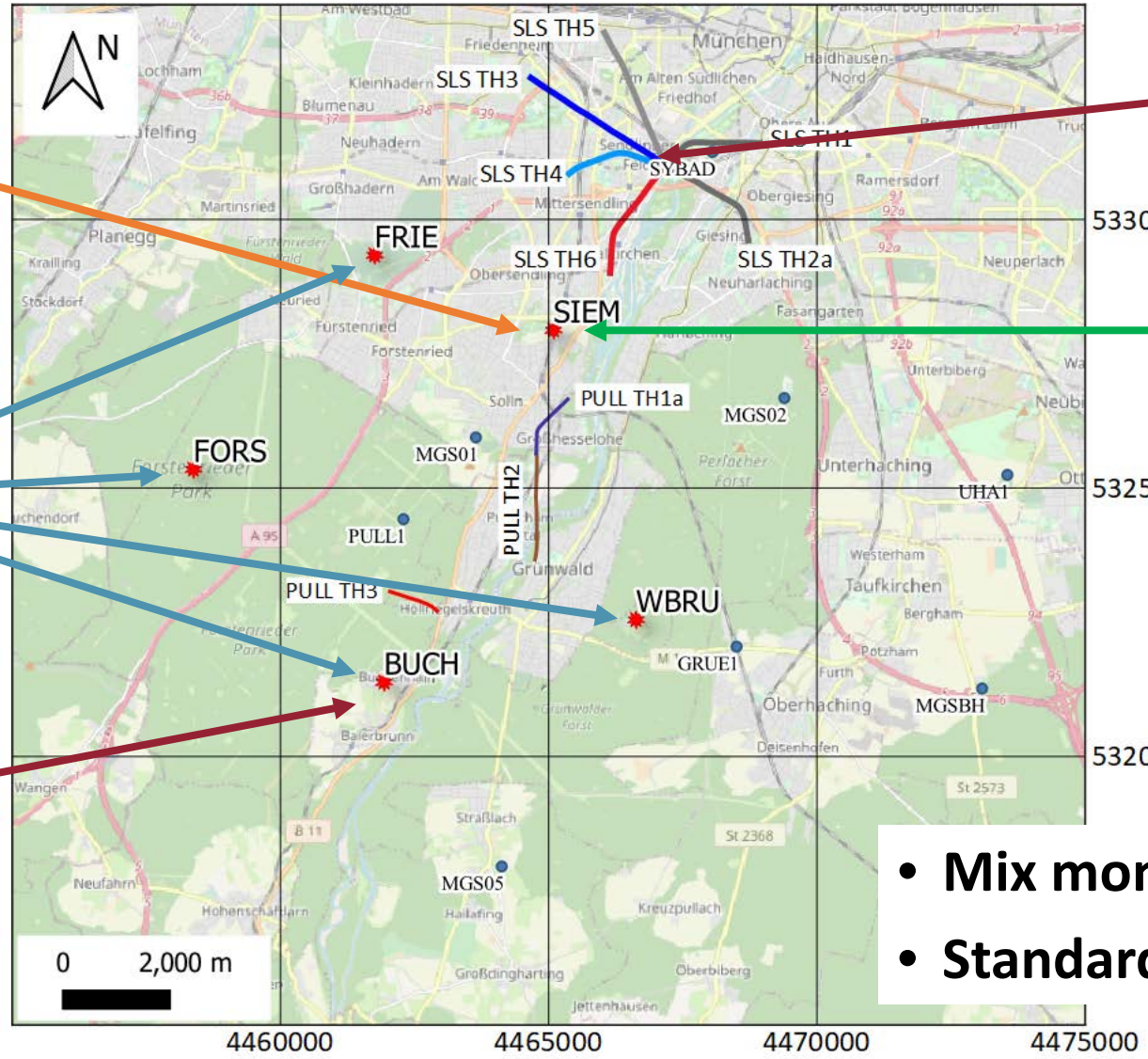
1 mini-array
9 × 3C-seismometers



4 × surface
3C-seismometers

Vertical (250 m) and surface
DAS and DTS cables



Vertical DAS cable
(TUM – GAB)

1 × downhole
3C-seismometer

- **Mix monitoring types**
- **Standard / new technologies**

Passive seismic monitoring design

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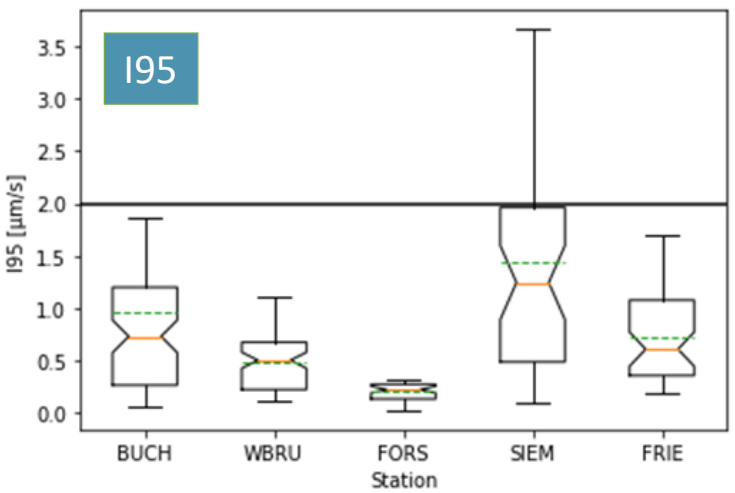
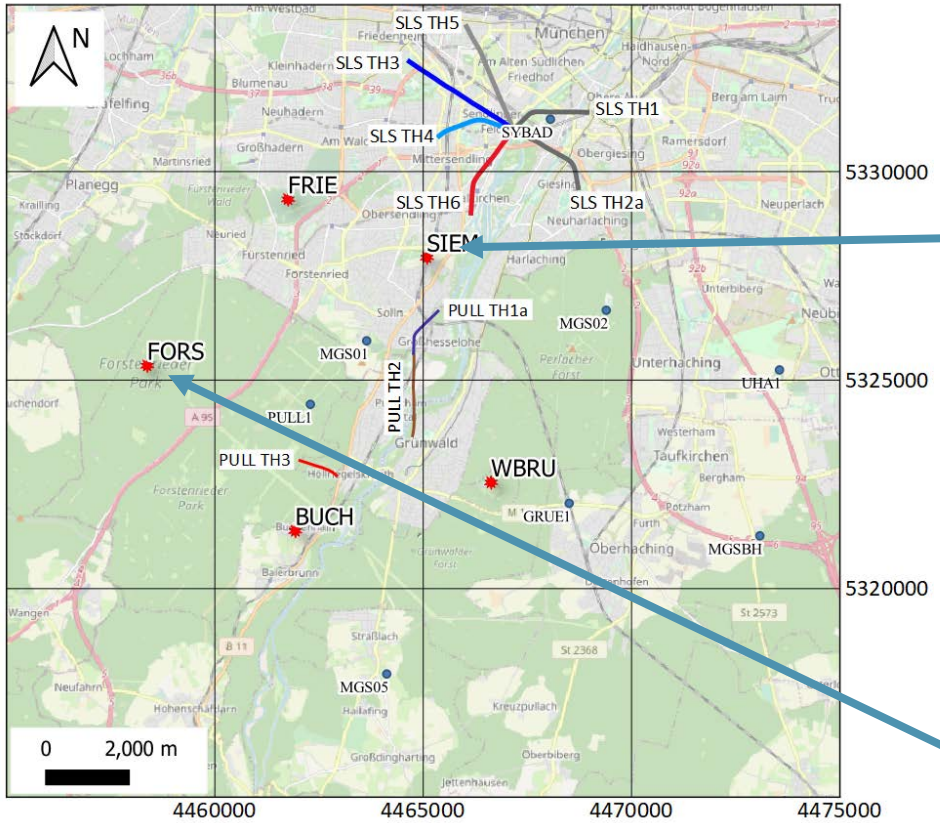
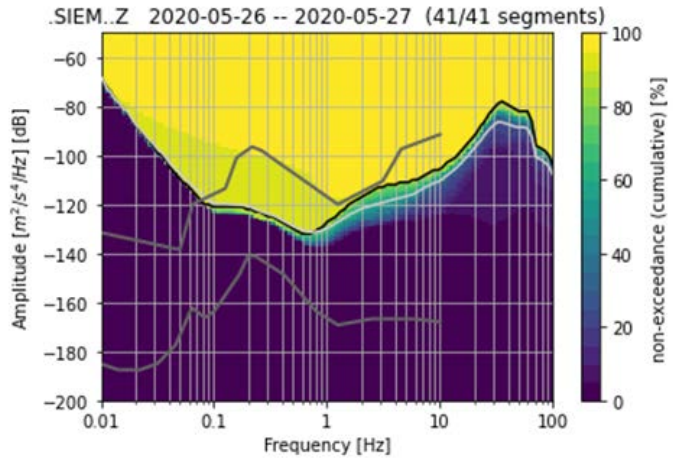
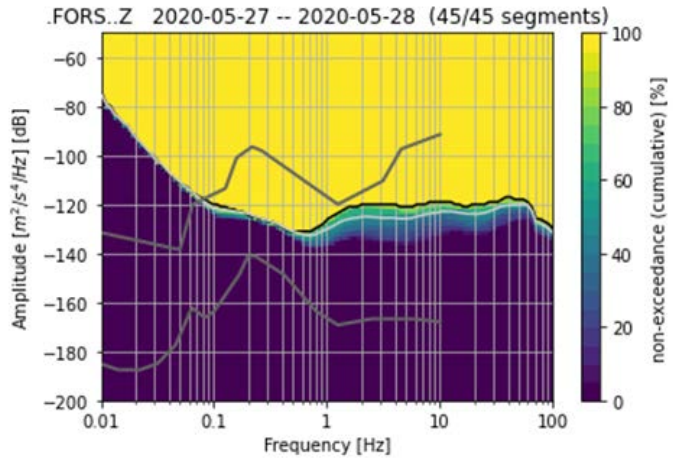
Seismic noise measurement campaign





Probabilistic Power Spectral Densities (PPSD)





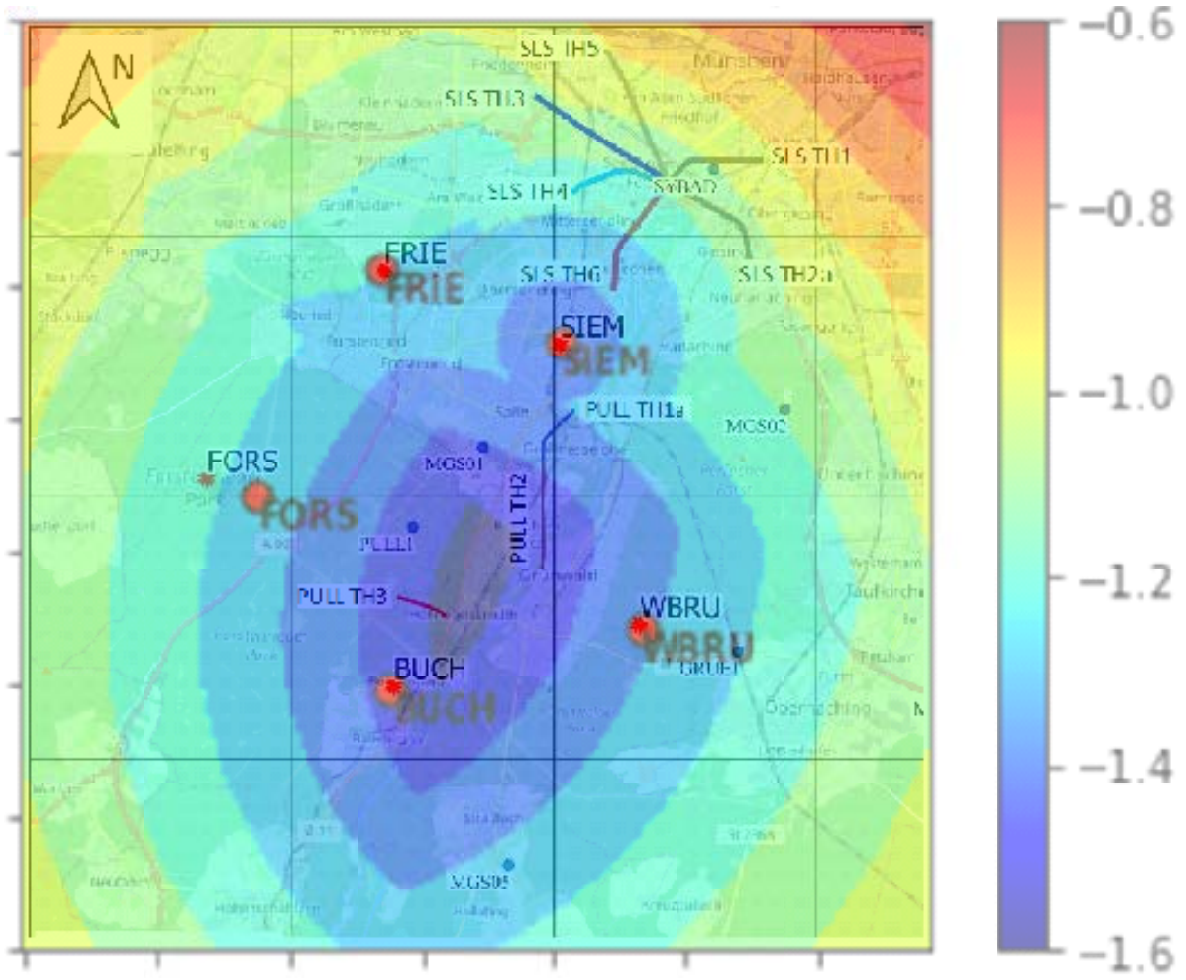
✔ **FKPE recommendations (2012)**

Passive seismic monitoring design

- Detection sensitivity estimate
  - SNR = 3
  - P-wave
  - 3 stations
  - 2250 m b.s.l.

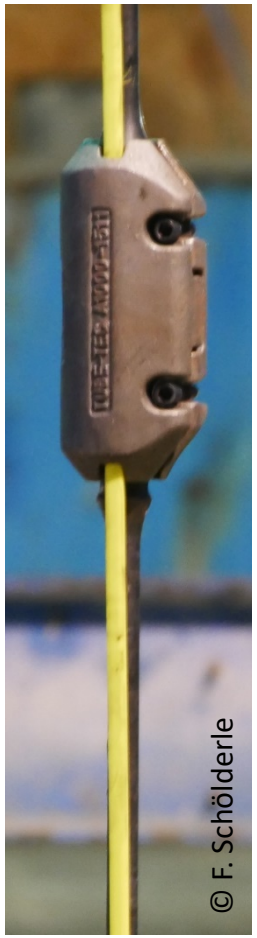
  - Below network: Mw= -1.3
  - At SLS: Mw = -0.8

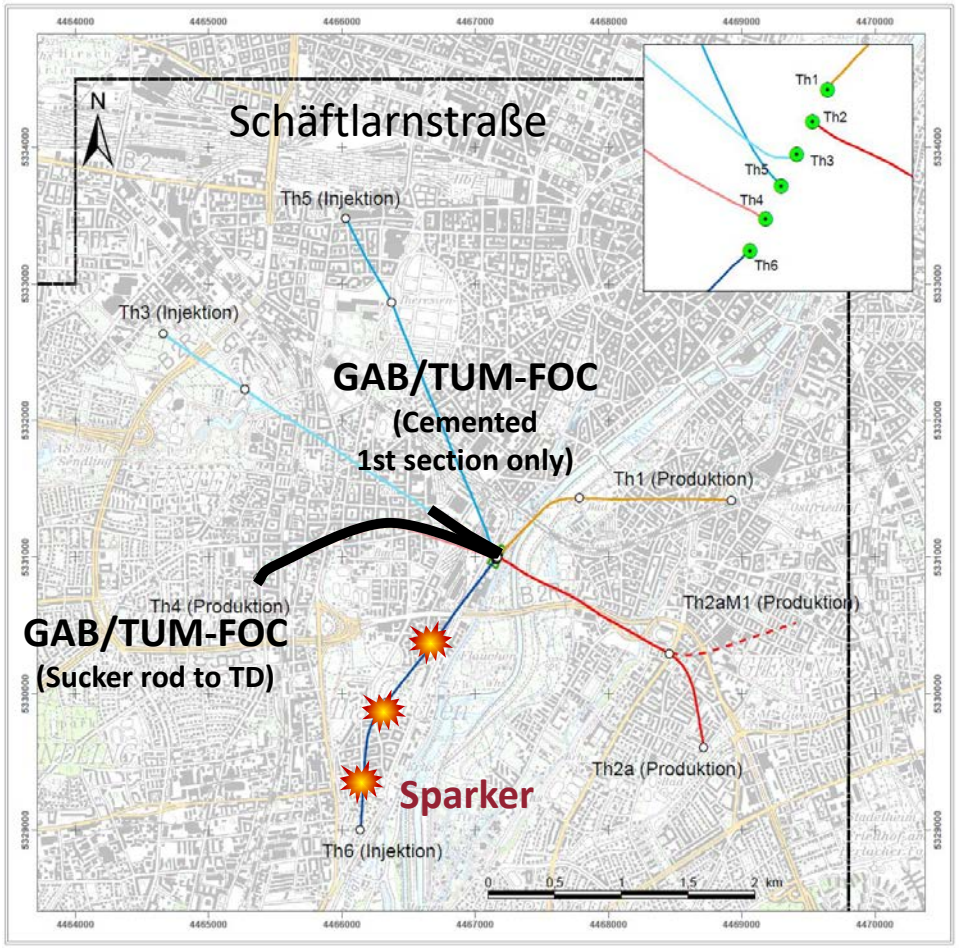
  - Doesn't account for
    - Downhole seismometer
    - DAS
    - External stations



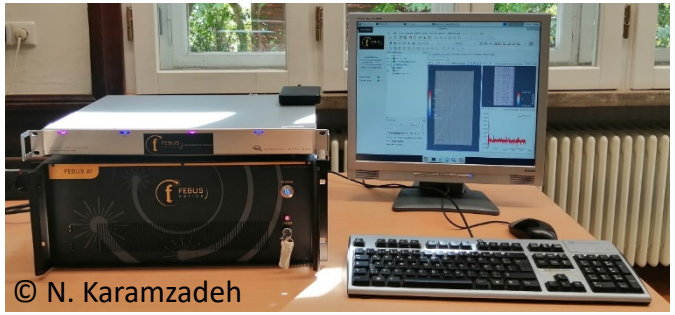
Active seismic cross-well survey

- Fibre optic cables



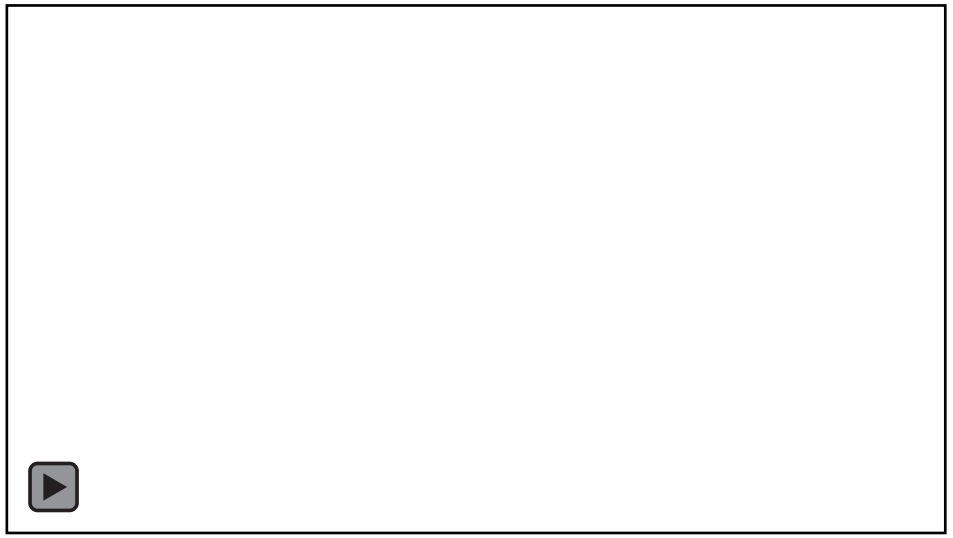


- Distributed acoustic sensing (DAS)
  - Scattering effect occurs everywhere along the fiber, the back scattering light contains the information of temperature and strain from where it was generated

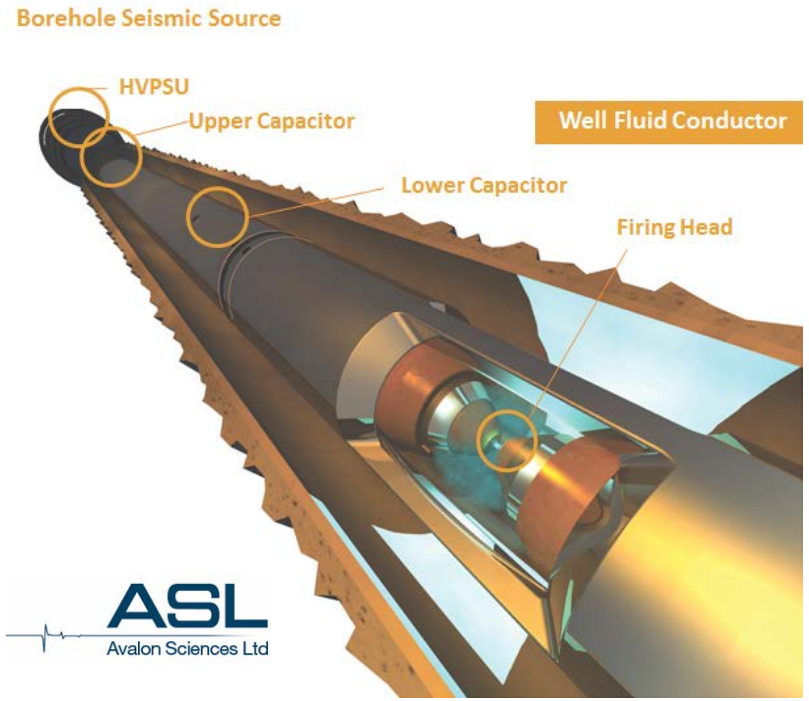


  - Strain rate along the fibre (or spatial derivative of the fibre particle velocity)
    - Spatial resolution: 1 to 50 m
    - Gauge length: 1 to 50 m
    - Sampling interval: 0.8 to 10 m

Active seismic cross-well survey

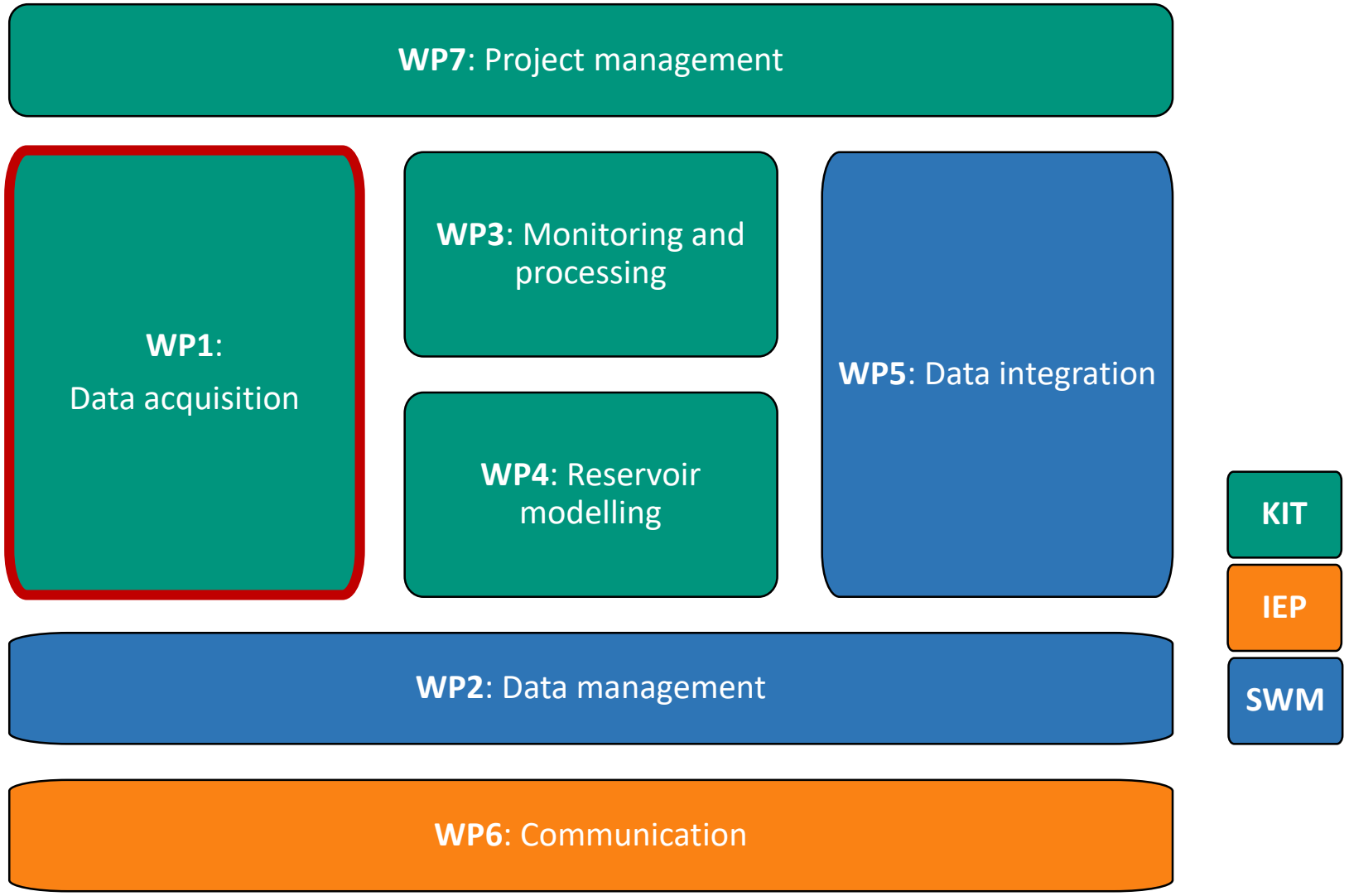


- 30s firing interval
- Firing T/B transmitted to surface
- Up to 150°C and 65 MPa



- Repeatable energy pulse
- 10 – 4000 Hz omni-directional
- Peak power 1000 Joules/shot

Work packages



Conclusion

- INSIDE project consistent and integrated with other past and running projects focusing on the geothermal exploitation of the Greater Munich
- Current focus is mainly on acquiring data
  - Active cross-well survey at Schäftlarnstraße
    - To improve P- and S-wave velocity models to decrease earthquake location errors
    - To improve reservoir imaging through tomography and finer interface resolution
    - To assess monitoring equipment
  - Deployment of passive seismic monitoring
    - To acquire low magnitude induced seismicity using mixed design and different tools
  - Deployment of GNSS and CR stations for deformation monitoring

Thank you

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Forschungszentrum Jülich

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